Natural Disasters and Central Bank Asset Purchases

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January 3-5, 2026

ASSA 2026 Annual Meeting
Philadelphia, PA

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Outline

Introduction

Introduction (1) - Increasing frequency of natural disasters

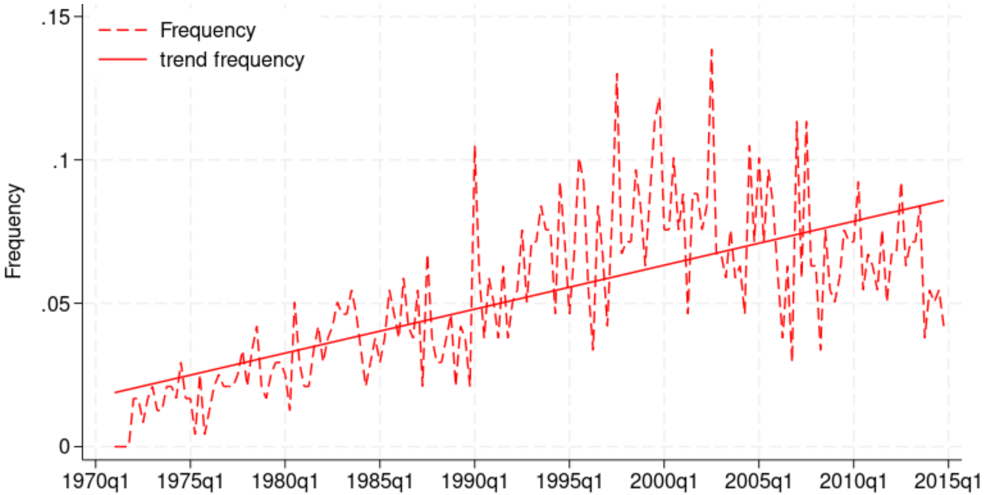

Figure 1: frequency of natural disasters - 1970-2015. Source: Fratzscher et al. (2020) and authors' calculations.

Introduction (2) - Monetary policy implications of natural disasters

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    - Central banks face inflation-output trade-off (supply-type shocks).
- **Disaster risk**: increases precautionary savings, reducing aggregate demand and inflation in the long-run (Cantelmo, 2022).
    - Harder for central banks to achieve inflation target; lower natural interest rate; ELB more likely to bind.

Introduction (3.1) - Natural Disasters and Term Premia

- **Financial markets reaction.** Increase in term-premium:
  - magnify output losses and reduce inflation (negative demand shocks);
  - potential disruption of monetary policy transmission;
  - risks for financial and macroeconomic stability (Bolton et al., 2020).

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- **Financial markets reaction**. Increase in term-premium:
  - magnify output losses and reduce inflation (negative demand shocks);
  - potential disruption of monetary policy transmission;
  - risks for financial and macroeconomic stability (Bolton et al., 2020).
- Formally investigate the effects estimating the following LP:

$$\Delta y_{i,t} = c + \sum_{j=0}^{J} [\beta_j S_{i,t-j} + \vartheta_j GDPpc_{i,t-j} S_{i,t-j}] + \nu_i + \nu_Y + \phi X_{i,t-1} + \sum_{l=1}^{L} \mu_l \Delta y_{i,t-l} + \varepsilon_{i,t}. \quad (1)$$

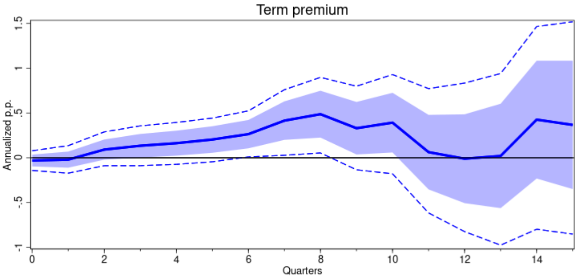
- $y_{i,t}$ is the term premium (i.e. difference between long- and short-term rates);
- $S_{i,t-j}$ is the natural disaster shock;
- Specification and data follows Fratzscher et al. (2020).

Introduction (3.2) - Natural Disasters and Term Premia: data

- Countries: 76 (36 OECD, 40 EMDEs);
- Sample: 1980Q1-2015Q4;
- Disaster shock:
  - Source: EM-DAT;
  - Weighted quarterly damage (% of pre-disaster GDP);
  - We include only climate-related natural disasters (i.e. no earthquakes).
  - We consider 90-99 percentiles (robust to alternatives).

	N. obs	Average damages (% GDP)	St. dev.
Disaster shocks	220	5.92	5.55

Introduction (3.3) - Natural Disasters and Term Premia



Notes: The figure shows the cumulated response of the term premium to large natural disasters over the period 1980Q1-2015Q4. Confidence bands refer to the 90% level (dashed lines) and a one standard deviation interval (shaded area).

- Evidence of higher term premia following large natural disasters, such that it might be desirable for central banks to intervene.
- Natural disaster of 1% of GDP on average increases the term premium by 0.5 p.p. at the peak.

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3. Are higher frequency or severity of natural disasters relevant for monetary policy?
   - Exploiting NGFS scenarios, asset purchases are needed unless further climate mitigation policies are implemented.

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  - under historical data and NGFS *Current Policies* and *Net Zero 2050* scenarios.

Literature

- Natural Disasters and monetary policy:
  - Fratzscher et al. (2020), Cantelmo (2022), Cantelmo et al. (2024): focus on short-term rate.
- Natural disasters and higher risk premia:
  - Painter (2020), Beirne et al. (2021), Cevik and Jalles (2022), Mallucci (2022).
- Central bank asset purchases:
  - Financial market stabilization: Bolton et al. (2020), Motto and Özen (2022).
  - APs above the ELB: De Fiore and Tristani (2019), Bigio and Sannikov (2021), Vissing-Jorgensen (2023).
- Our contributions:
  - Study the role of APs in addressing the effects of natural disasters both after disasters strikes and in normal times and regardless of the ELB.
  - Evaluate APs under NGFS scenarios.

Model

Model (1) - Overview

New-Keynesian representative agent model with:

- Epstein-Zin preferences.
- Financial intermediaries (as in Carlstrom et al., 2017): real effects of APs.
- Standard New Keynesian Phillips curve (Calvo rigidities).
- Monetary policy:
  - short term rate R_t;
  - asset purchases B_t^{CB}.
- Natural disasters affecting: capital, TFP and term-premium.

Model (2) - Natural Disasters

- Stochastic process for disasters (Fernández-Villaverde and Levintal, 2018):
  - strike: $d_t = 1$ with probability p_d,
  - size: determined by a time-varying force θ_t

$$\log \theta_t = (1 - \rho_\theta) \log \bar{\theta} + \rho_\theta \log \theta_{t-1} + \sigma_\theta \epsilon_{\theta,t}, \quad \epsilon_{\theta,t} \sim \mathcal{N}(0,1) \tag{2}$$

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- Two sources of uncertainty:
  - **Timing**: agents only know the (fixed) probability of a disaster strike but know about the realization only when it happens.
  - **Magnitude**: agents only know the average impact of a disaster but the actual size cannot be known ex-ante.

Model (3) - Natural Disasters impact on capital and TFP

- Shock is realized at the beginning of the period so the actual capital k_t is a function of the previous period capital optimal choice k^*_{t-1}

$$k_t = k^*_{t-1} e^{-d_t \theta_t} \tag{3}$$

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- TFP, A_t^{agg}, has a permanent and a stationary component to capture realistic dynamics$\rightarrow$ disaster strikes have permanent effects followed by partial recoveries (Hsiang and Jina, 2014; Bodenstein and Scaramucci, 2024):

$$\log A_t^{agg} = \log A_t + \log A_t^T, \tag{4}$$

$$\log A_t = \log A_{t-1} + \Lambda_A - \omega (1-\alpha) d_t \theta_t, \tag{5}$$

$$\log A_t^T = \rho_a \log A_{t-1}^T - (1-\omega)(1-\alpha) d_t \theta_t, \tag{6}$$

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- When a disaster hits, the long-term rate on loans and hence the term premium increase as a proxy for financial markets overreaction.

$$R_{t+1}^L = \frac{1 + \kappa_L P_{L,t+1}}{P_{L,t}} e^{\eta \tau_t} \tag{8}$$

$$\log \tau_t = \rho_\tau \log \tau_{t-1} + d_t \theta_t \tag{9}$$

- The size of the overreaction is determined by η.

Model (5) - Monetary Policy Instruments

1. Standard Taylor rule

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left(\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\Pi} \left(\frac{\frac{y_t}{y_{t-1}}}{\exp\left(\Lambda_y\right)}\right)^{\gamma_y}\right)^{1-\gamma_R} \tag{10}$$

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3. Asset purchases to tame financial markets overreaction (+TR) (APs)

$$\frac{\bar{B}_t^{CB}}{\bar{B}^{CB}} = \left(\frac{\bar{B}_{t-1}^{CB}}{\bar{B}^{CB}}\right)^{\gamma_b} \exp\left(\frac{d_t TP_t}{dTP}\right)^{\gamma_{bTP}} \tag{12}$$

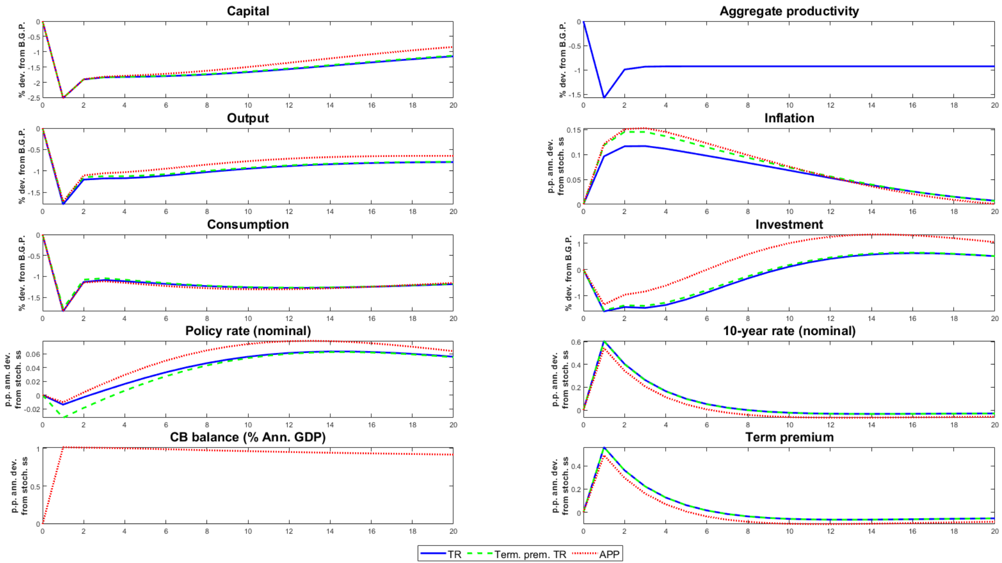
Calibration of disasters: historical data and scenarios

- Baseline calibration: EM-DAT, OECD 1960-2018.
- Scenarios based on Chavleishvili and Moench (2025):
  1. Costly disaster index (CD) of Ludvigson et al. (2021), US 1980-2019;
  2. Estimate distribution of CD under *Current Policies* and *Net Zero 2050* scenarios using corresponding global average carbon concentration from 2020 to 2040.
  3. Retrieve increase in annual probability and average impact of disasters;
  4. Apply these effects to our baseline calibration (damages are rescaled by GDP projections).

Scenario	Disaster probability	Average damages (% GDP)
Baseline	1.2%	1.8%
Net Zero 2050	2.2%	1.8%
Current policies	10%	1.8%

Results

Dynamic Effects of an Average Disaster Shock



- To compare APs and TP Taylor rule: effect on output on *impact* is equalized by construction.
- Deviating from Standard Taylor rule:
  - term premium is only slightly affected;
  - mild stimulus to consumption, investments and output;
  - temporarily higher inflation.
- Using asset purchases:
  - stronger effect on the term premium;
  - boosting investments and sustaining output;
  - with similar additional inflation.

Results - Distributions in normal and disaster times

- What are the stabilization properties of monetary policy instruments when disasters of different sizes occur? What happens in the long-run due to disaster risk?

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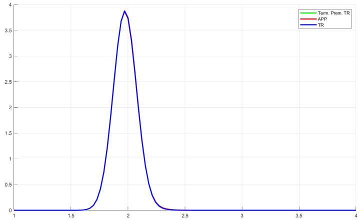
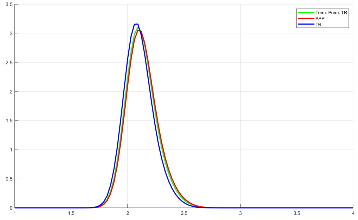
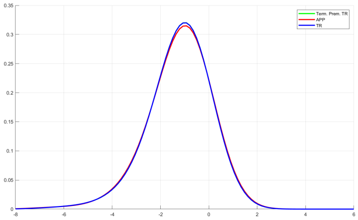
Baseline Calibration



(a) Inflation - Pre-Disaster



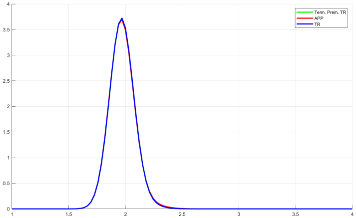
(b) Inflation - Post-Disaster



(c) Output Gap - Pre-Disaster

(d) Output Gap - Post-Disaster

Net zero 2050



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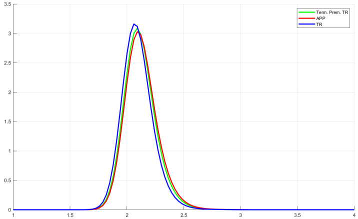

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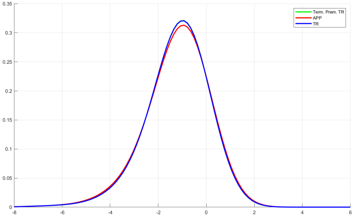

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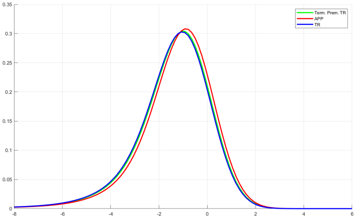

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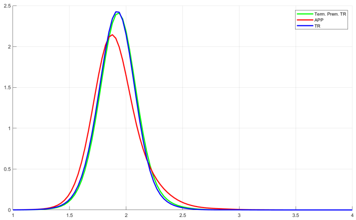

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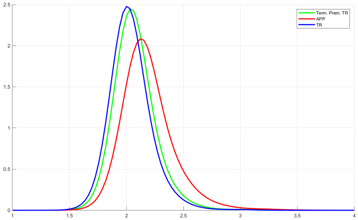

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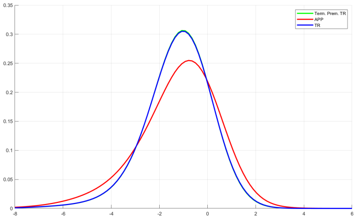

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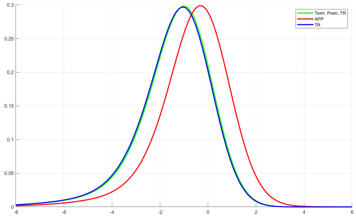

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- APs not needed under *"Net Zero 2050"* scenario.
- Significantly positive effects under *"Current Policies"* scenario with more frequent shocks.
- APs appear effective at moving the entire distribution of output to the right while temporarily moving that of inflation rightward and increasing its positive skewness, especially with more frequent events.

Conclusions

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5. APs would be needed to provide significant stabilization unless further climate mitigation policies are implemented.

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